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AUTHOR House, Garvey; Zelhart, Paul F.  
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## ABSTRACT

The complexity (fractal dimension value) of responses to the Rey-Osterrieth Complex Figure Test (ROCFT) between 10 undergraduate students with learning disabilities and a comparison group of 10 students without learning disabilities were compared. The fractal value of responses was assessed under three conditions (copy, immediate, and delay) by means of a box-counting algorithm. There were significant differences between the two groups across response conditions and a significant difference between the copy condition and the two memory conditions. The results of this study suggest that the fractal dimension is an effective metric for differentiating students with and without learning disabilities. The results also suggest that students with learning disabilities lack effective planning and organizational strategies that result in lower copy scores on the ROCFT. (Contains 25 references, 3 tables, and 2 figures.) (Author/SLD)

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Differences in the  
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Students with and without Learning Disabilities  
Garvey House and Paul F. Zelhart  
East Texas State University

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Running head: FRACTAL DIMENSION OF COMPLEX FIGURES

## Abstract

The complexity (fractal dimension value) of responses to the Rey-Osterrieth Complex Figure Test (ROCFT) between students with learning disabilities and a comparison group of students without learning disabilities were compared. The fractal value of responses was assessed under three conditions (copy, immediate, and delay) by means of a box-counting algorithm. There were significant differences between the two groups across response conditions and a significant difference between the copy condition and the two memory conditions. The results of this study suggest that the fractal dimension is an effective metric for differentiating students with and without learning disabilities. The results also suggest that students with learning disabilities lack effective planning and organizational strategies which result in lower copy scores on the ROCFT.

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Some behavioral characteristics of individuals with learning disabilities (LD) are similar to those exhibited in patients with brain injury. Goldstein (1939) noted perceptual impairments of figure-ground relationships, distractibility, and preservation in brain-injured soldiers returning from WWI. Werner and Strauss (1940), Strauss and Lehtinan (1947), Strauss and Kephart (1954), and Cruickshank (1960) developed medical models to explain these behavioral characteristics through the study of brain-injured children.

Although present definitions of LD vary, neurological dysfunction is a common presumption to most definitions (Leaner, 1989). Two basic features of definitions of LD are described in Public Law 94-142: (a) individuals with LD have intelligence scores within the normal range and (b) these students have substantial academic difficulties resulting in a

significant discrepancy between their academic achievement and their expected performance level. The U.S. Office of Education's definition of learning disability reflects a medical model for LD and includes terms like "brain injury" and "dyslexia" (Westman, 1990). A more recent definition by the National Joint Committee on Learning Disabilities (Hammill, Leigh, McNutt, & Larsen, 1981) states that learning disabilities may be due to a central nervous system dysfunction. A failure to achieve a single definition for LD may reflect the heterogeneous nature of the disorder.

One source of variance associated with LD is neurophysiological. Duane (1986) identified neurophysiological correlates in learning disabled subjects through positron emission tomography. Other methods reported by Rourke (1985) include neuropsychological tests such as the Halstead-Reitan (Halstead, 1947; Reitan, 1955) and pattern analyses of the subscales of the Wechsler Intelligence Scale for Children-Revised (WISC-R) (Wechsler, 1981). The Halstead-Reitan and the WISC-R are extensive

assessments which require a trained clinician to administer and score.

Assessment instruments often used to discriminate between students with and without LD include intelligence tests such as the WISC-R and achievement tests such as the Woodcock-Johnson Psychoeducational Test Battery (Woodcock & Johnson, 1977). Significant discrepancies of more than 15 standard score points between capacity (as measured by intelligence tests) and achievement tests commonly identify students with LD (Hammil et al., 1981). Because of the time and expense required for administration of these instruments, screening and or assessment is not usually performed prior to the recognition of learning problems. The following study describes an inexpensive, brief, and potentially effective method for screening for learning disabilities. The purpose of this study was to compare the complexity of responses, using an application of fractal geometry, to the ROCFT between learning disabled students and a comparison group of normals matched on age, classification, and gender.

### Method

Subjects Twenty undergraduate volunteers (10 with LD and 10 without LD) served as subjects. Each group had equal numbers of males and females. Subjects with LD (LD-group) were drawn from a university tutoring program which certified their LD status through professional diagnosis. No restrictions were made concerning the type of learning disabilities. Subjects without LD (NLD-group) were randomly drawn from a group of students enrolled in an undergraduate psychology class and matched with subjects from the LD-group on age, years of education, and gender. None of the subjects had been (a) hospitalized for head injury, (b) lost consciousness from head injury, or (c) were taking psychoactive medication. LD-group subjects had been assigned to special education programs in primary or secondary school. NLD-group subjects had not been so assigned.

Materials The Rey-Osterrieth Complex Figure (ROCFT), developed by Rey in 1941 and Osterrieth in 1944 (Lezak, 1983), is a neuropsychological test of visual-spatial-constructional functions and non-verbal (visual) memory and is often used for patients with brain injury. The

ROCFT (Figure 1) consists of a single complex geometric figure which provides a good indication of planning and organization ability as well as selective remembering, perceptual distortion, and graphomotor coordination (Waber, Bernstein, & Merola, 1989). The ROCFT stimulus has a base rectangle measuring 4 in. X 3½ in. and is drawn horizontally on 8½ in. x 11 in. white paper. A common administration procedure requires the subject to first copy the figure and then (second) reproduce it immediately from memory and (third) after a brief delay, typically about 20 minutes. Memory components of the ROCFT may place greater demands on subtle pathology and provide a sensitive screening measure for learning disabled students.

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Insert Figure 1 about here

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The theoretical basis for the design and scoring system is neuropsychological. Structure-function relations demonstrated in brain-damaged individuals "serve to illuminate the natural architecture of cognition" (Allport, 1980, p. 28). Rey devised the ROCFT primarily for the purpose of assessing cognitive



abilities of brain-damaged patients. The ROCFT appears to be sufficiently complex to provide a good indication of planning and organization skills as well as of selective remembering, perceptual distortion, and graphomotor coordination (Lezak, 1983).

Generally, patients with left hemisphere lesions attend to the figure's global aspects, whereas those with right-hemisphere lesions attend to parts and details. This reflects the complementary contribution of the noncompromised hemisphere (Milberg, Hebben, & Kaplan, 1986). Similarly, anterior lesions are associated with defects of executive function, planning and organization, whereas posterior lesions are associated with breakdown of constructional skill (Stuss & Benson, 1986). Although these two axes are conceptually orthogonal, they are not independent from a functional standpoint. There exists a dynamic relationship between them.

Although the language of the non-dominant hemisphere is not clearly understood, relationships apparently exist between performance of patients with non-dominant injury and complex visual, auditory, and spatial functions that are primarily non-verbal in

nature (Taylor, 1968). Construct validity of the recall of non-verbal material such as simple geometric drawings and faces was addressed by Milner (1975). In right temporal lobe ablation patients there was a significant difference between pre- and post-operative performance. Left temporal lobe ablation patients, on the other hand, did not exhibit similar performance decrement. Other validity investigations have focused on the general sensitivity of the ROCFT to brain injury as well as its ability to detect deficits of visuospatial memory thought to the right temporal lobe (Milner, 1975).

The ROCFT consists of 18 scorable units. Traditional scoring systems require a trained clinician to use a detail analysis to assign values to specific elements of the response (Lezak, 1983). Elements of a response are compared to the standard and a score (from 0 to 2) is assigned on the basis of location and completeness.

An alternative method of assessing responses to complex figures was developed by House and Zelhart (1993). Scores were assigned to responses by computing the fractal dimension. The fractal dimension is a

measure of geometric complexity. Its computation is based on a power law which represents the change in unit area relative to the scale of measurement. This method does not require a trained clinician and responses are evaluated directly by commercially available computer equipment. Direct scoring of responses by computer-aided devices provides for high scoring reliability.

Design and Procedure Administration procedures detailed by Lezak (1983) were followed. Subjects were asked to copy the ROCFT or draw it from memory immediately after its removal and after a brief delay of 20 minutes. Group testing procedures were used in a traditional classroom setting. Each group administration consisted of 5 students. All subjects received identical materials and instructions. Each subject was presented a sealed packed containing the ROCFT, five sheets (8½ X 11 in.) of unruled white typing paper, a 0.25mm fine point roller-type black ink pen, a demographic information sheet and a set of mathematics problems used as an interpolation task. Subjects were asked to remove all items from the materials packet. During the copy condition, the

experimenter presented the ROCFT and instructed subjects to place the figure so that the length runs along the subject's horizontal plane with the small cross in the upper left corner. An overhead transparency projected the correct orientation on a screen. Subjects were given the following instruction for the copy condition:

Use the pen and paper provided to copy the figure as best you can. If you need to make corrections, I will provide Liquid Paper™ to cover your mistakes. When you are finished, place your drawing and the figure in the packet.

After subject completed the copy condition, the following instructions were given for the immediate memory condition:

At this time, please draw the figure from memory as best you can. If you need to make a correction, I will provide Liquid Paper™ to cover your mistakes. When you have completed your drawing, return it to the packet.

After all subjects completed the immediate memory condition, subjects were asked to complete the demographic information form and answer the mathematics problems on the paper provided in their packet. Mathematics problems, consisting of addition and multiplication of two digit numbers, served as an interpolation task. After twenty minutes expired, subjects were given the following instructions for the delay memory condition:

At this time, please return the demographic information form and math problems to the packet and place the packet on the floor beside you. Remember the figure I asked you to copy and then draw from memory? At this time draw the figure again from memory as best you can. When you have completed your drawing, return it to the packet.

After completion of the delayed memory condition, all testing materials were removed from the desks and subjects were thanked for their participation.

### Results

Means and standard deviations of the fractal dimension of responses to each phase of the ROCFT were computed. The results are presented in Table 1 and Figure 2. The LD-group had lower mean fractal dimension values across all treatment conditions than the NLD-group. That is, the responses of subjects with LD to the ROCFT were less complex than the comparison group. Lower fractal dimensions are associated with less complexity; the responses were simplified by eliminating structural elements of the ROCFT.

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Insert Table 1 and Figure 2 about here

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Differences between the LD-group and NLD-group across three treatment conditions were tested using the MANOVA method for analyzing mixed repeated measures designs (O'Brien & Kaiser, 1985). The results are presented in Tables 2 and 3.

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Insert Tables 2 and 3 about here

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The assumptions for repeated measures designs were tested. There were no significant violations of

assumptions. There was a significant between subjects main effect. Averaged across all treatment conditions, the fractal dimensions of responses to the ROCFT of the NLD-group were significantly different than LD-group. There was a significant within subjects main effect. A multiple F-test was used to compare differences among the three treatment conditions across all subjects. The copy condition was significantly different from the immediate and delay memory conditions. The responses under the copy condition was more complex than either of the memory conditions.

#### Discussion

The results are consistent with the notion that there are quantitative differences between students with learning disabilities and students without learning disabilities with respect to responses to the ROCFT. Generally, students with LD had significantly lower fractal values than students without LD averaged across the three treatment conditions; responses of students with LD were significantly less complex than those of students without LD.

A cognitive model of learning provides for an executive component which is responsible for planning

and organization. Encoding ability is a function of planning and organization of the stimulus (Craik, 1979). In the copy condition of the ROCFT, subjects must be able to organize the percept and form a gestalt; that is, subjects must first consider the figure as a whole. Some students with learning disabilities do not have effective planning and organizational strategies (Klipcera, 1983) which suggest a reason for low scores on the copy condition. For many subjects with brain dysfunction, the outside rectangle of the ROCFT is not perceived and therefore they are unable to form a gestalt (Lezak, 1983). Poor construction of the ROCFT is characterized by low copy scores. Unless the structural elements of the ROCFT are adequately encoded, students are unable to recall them. The results of this study support a notion of encoding deficits in students with LD.

The use of the fractal dimension of responses to the ROCFT provides a reliable and efficient method of screening for students with LD. The current use of the fractal dimension method is best suited to screening for global brain dysfunction such as learning disabilities. Two objections to screening (time and



expertise) are overcome using the method presented. Using commercially available computer software and equipment provide a quick and reliable method for holistic scoring of complex figures such as the ROCFT. Additional research may show how the fractal dimension can be used to differentiate other populations presenting neuropathology.

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Table 1

Means and standard deviations of fractal scores of responses to the ROCFT between students with and without LD across three treatment conditions (copy, immediate, and delay).

<u>Group</u>	<u>Condition</u>	<u>M</u>	<u>SD</u>
Learning Disabled			
	Copy	1.316	.013
	Immediate	1.276	.036
	Delay	1.253	.044
Normal			
	Copy	1.372	.021
	Immediate	1.322	.034
	Delay	1.301	.037

Table 2

Repeated measures analysis of variance between students  
with and without LD across three treatment conditions  
(copy, immediate, and delay).

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<u>Source</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>p</u>
Between subjects	.030007	1	.030007	14.44	.002
error	.029090	14	.002078		
Within subjects	.037275	2	.018638	27.86	.005
Group by Treatment	.002120	2	.001060	.16	.854
error	.01731	28	.000669		

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Table 3

Means and standard deviations of the three treatment conditions (copy, immediate, and delay) across all subjects.

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<u>Condition</u>	<u>M</u>	<u>SD</u>
Copy	1.324	.039
Immediate	1.293	.041
Delay	1.276	.043

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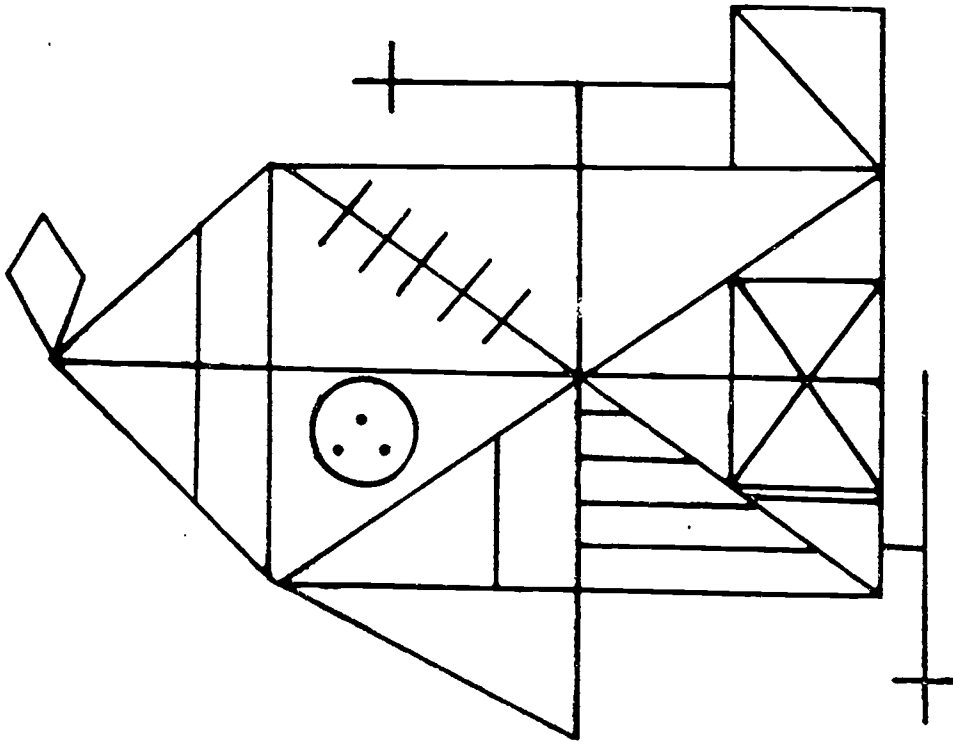


Figure 1

The Rey-Osterrieth Complex Figure.

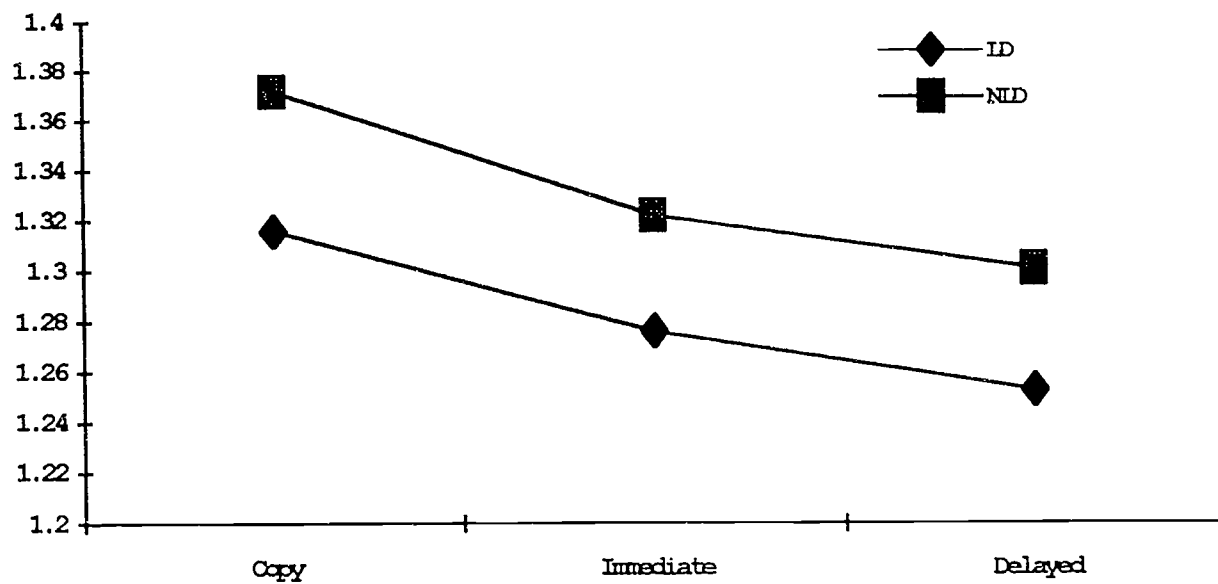


Figure 2 Fractal values of responses to the ROCFT for the copy, immediate, and delayed conditions for students with and without learning disabilities.